Design Elements of a Telemedical Medical Record

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Computerized Patient Records are becoming telemedical and multimedia documents. They should accompany the patients their whole lifetime and collect data from many different sites. Special requirements are arising to fulfill these demands. A prototype of such a system was designed and implemented at the university hospital in Großhadern, Germany to show its feasibility, discuss the design elements and demonstrate its capabilities. A Flexible data model, interpretable contents, open communication structures and physical compilation are the cornerstones of this approach that allows communication via Internet or Smart cards.

INTRODUCTION

Demands for the application of computers in medical care are rising[1]. They not only have to support administration and legal issues but also have to increase quality of patient care and to support health care professionals[2]. To demonstrate the capabilities of current techniques a prototype of a Computerized Patient Record (CPR) was implemented on a SUN workstation whose graphical user interface (GUI) allows the presentation of mulitimedia documents. The main goal of this approach is to support nurses and physicians and to record a patient's history throughout his whole life (pre-birth and post-death record)[3]. To deal with the topic of a lifelong patient record the main focus was put on flexibility of the system in terms of data model, data exchange and presentation of data.

DESIGN ELEMENTS

The project started with theoretical discussions about the basic elements of which a Computerized Patient Record System (CPRS) should be constructed and about their properties[4]. The paramount demand for such a system is flexibility. Documents that are to be used for over 80 years (lifelong record) cannot be based on a rigid data model. Information recorded on such a system depends on medical progress and will vary tremendously over this timespan. Multimedia objects from narrative data to images, video and audio have to be stored. Patient records also have to fit to a patient's diagnosis and problem list which leads to a potentially large number of different items. Also the ways to access the data differ between medical doctors and have to reflect the medical problems under question[5] such that the contents of the record has to be restructured for every view. A small number of basic building blocks for a CPRS were elaborated:

1. **Data Model**
   The data model (DM) defines the structure of all possible entries, must not restrict future demands and has to allow different views on the data. Patient records may be stored in hospital data bases, transmitted over communication lines or recorded on Smart cards. These techniques must be supported by the DM. Similar to traditional paper records this type of CPR is physically located on the patient's ward or at the general practitioner which also has implications on the DM.

2. **Presentation types**
   Every item in a patient record must be handled, displayed, passed on and so forth. Corresponding to the possible data types (figures, text, images etc.) basic methods exist for displaying them in an inherently object oriented approach. The set of items in a lifelong patient record will increase in accordance with the age of the record (i.e. patient) and the medical progress. The number of methods for their presentation implemented in a CPRS has to be expandable on the same scale.

3. **Communication**
   The integration of a Computerized Patient Record in a general environment is a major aspect of the development. Standards (like HL7, EDI) are very important for enabling access other systems. For data exchange between computerized patient records, communication should be based on the data object dictionary defined by the data model. Active components (knowledge server) can be included in a hospital environment to enhance the functional capabilities of the entire system.

4. **Interpreter**
   The interpreter makes the system work. Every action is defined (i.e. programmed) in a special language. These CPR-programs are executed during the runtime of the CPRS. The separation of hard coded methods and the interpreter operating on them gives flexibility to define and evaluate problem oriented views for specialized problems. Also further development of the core tool set can be done by computer experts whereas the medical knowledge that is implicitly or explicitly available through such a system can be enhanced by medical experts.

DATA MODEL

The DM defines the medical concepts (like blood pressure) that can be recorded in the electronic patient file and handled by the patient record system. The concepts are based on technical objects (like figures, text, video) whose properties and relations are explicitly defined in a data object dictionary with a rather flat and simple hierarchy (Fig. 1).

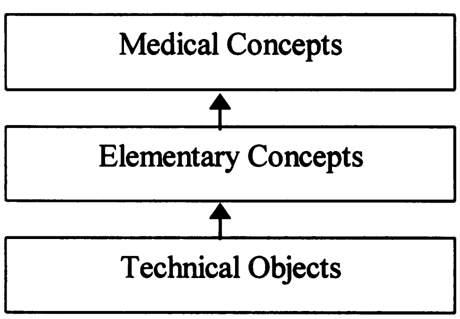

Fig. 1: Hierarchy of Medical Concepts

This corresponds to our philosophy of flexibility because data will be structured during runtime according to the view on the patient data rather than during the design phase of the database. The requested aggregation of patient data and the context of its usage is hardly predictable during data entry or the design phase of the data base. Interdependencies imposed on elements of the CPR will, with a high probability, prove improper during the presentation phase of the data.
The hierarchy of medical concepts consists of two levels. Elementary items (like a single lab value) are constructed from the technical objects and are specified by a number of possible attributes (Fig. 2). Items can be clustered to enhance performance. This step cannot be repeated because iterated clustering or non-unique assignment of single items to clusters would lead to a complex structure of interdependencies which is not intended by this approach.

- Identification (Name, Number)
- Technical Object (like Number, Text)
- Field Length, Format
- Unit
- Minimum, Maximum (Numbers only)
- Reference to Catalogs (ICD, SNOMED)
- Help- or specialized Information
- Activate procedure before recording, for display
- Classification
- Owner
- Validity of item

Fig. 2: Properties of elementary medical concepts

This metalevel defines properties and the relation of medical concepts. A general technical concept for physical data storage shows how data can be recorded in relational data bases, stored on Smart cards or transmitted over communication lines. The tagged file format gives needed flexibility and allows explicit interpretation of medical items (Fig. 3).

- Medican Concept Identification
- Value
- Patient Identification
- Time of recording
- Owner
- Data Quality
  - Checked, Doubtful, wrong
- Backup Status
  - Existing, Archived, Locked
  - Sent / Received
- Comments

Fig. 3: Structure of recorded entries

Independent of the storage media every item is recorded with an identifier of the medical concept which allows to retrieve additional information about the recorded value from the DM and to interpret the contents of the record.

PRESENTATION TYPES

Medical items must be modified, displayed and communicated. A set of basic methods exists that allows the manipulation, presentation and communication of medical items that are controlled by a large number of parameters. Presentations must be adapted

to specialized needs of individual clinics and wards, having to correspond to the diagnosis and problems of the patient. This can lead to a large number of different presentations.
Possible types are forms, graphs, images or narrative data. The basic functions are activated in an object-oriented-like manner according to the technical object type they belong to which makes definition of CPR-programs easier.

Forms

Forms are the main means for displaying and entering information. Both patient centered and patient independent information can be displayed. General information can be included to support health care professionals in diagnosis and therapy. An example is shown below (Fig. 5)

Graphs

The x-axis of graphs always represents time. The unit is defined in the presentation. This is to ensure a fixed view independent of the individual data. Scales of the y-axis are either fixed or adapted to the range of patient data. Numerical data is not the only type of data that can be presented. Events can be shown as marks on the graph.

Images

Images or videos shall be displayed annotated and in combination with reports. The main focus is on displaying images on monitors on the ward or at the office of a general practitioner. For more sophisticated demands there is an interface available to activate image manipulation programs.

Narrative Data

Memos, comments and letters can be handled by this CPRS. Support in report writing is included in the system. Text modules can be defined and selected from a panel. The corresponding text is inserted in the document at cursor position. Manual insertions or alterations are possible.

COMMUNICATION

The computerized medical record is integrated in a medical environment via communication. Standard techniques (like HL7, EDI and EDIFACT, DICOM) are important to exchange data from and to other systems in the hospital. Communication between CPRs benefits from the common data model. Communication is an inherent functional capability of the presentation module. Output can be sent to a computer screen, a printer, a fax or transmitted over a digital network. This allows the definition of messages like forms with the addition of an address. Information between computerized patient records is always exchanged as a set containing item-identification, time of recording (optional), status information (optional) and value.
Every message starts with a header stating the addressee and a message identification. The message identification does not necessarily define the structure or the content but the interpretation of the message. This allows the definition of a single message for order entry. The content of the message differs according to the order requested. The addressee interprets the content on the basis of the data object dictionary.
Communication can take place between different locations within or outside a hospital. Possible communication partners within a hospital are CPRs, ancillary departments, administration, knowledge server.
The latter partner is of special interest. It can provide highly sophisticated functions e.g. adverse drug effects or incompatibilities can be checked. The large number of possible interactions and the need for rapid update does not allow the implementation of the above in the medical record system itself but could be provided by the departments.
Besides the structured data exchange format developed for communication between CPRs there also exist communication modules for record oriented devices. Entries of a CPR can be transformed in a fixed block length ASCII format that is suitable for data exchange with many traditional mainframe (COBOL) programs. Transformation of the data format is controlled by tables. This interface is also capable of reading data delivered in this format.

INTERMEDIATING MODULE

Analysis, presentation and communication of patient data is performed by an interpreter integrated into the computerized patient record system. This interpreter allows all control statements of a standard programming language, together with the powerful set of basic functions. Every action that should be performed has to be defined on the basis of the available data and the associated basic functional capabilities. The data object dictionary explicitly describes the properties of entries in the CPR. The interpretation of these commands is performed during runtime of the system which gives additional flexibility to the system. Modification or augmentation of or to the existing system can be performed without interfering with other parts of the CPRS. Every presentation is defined as a set of interpreter commands that is stored in a single file or a data base. They are activated through events (e.g. user interaction, watch dog functions, incoming messages). References to programs can also be recorded in the medical records to record applicable views and to enhance the use of standards throughout the treatment process.

EXAMPLES

The following two examples show the benefits of this concept. The first one supports physicians planning a chemotherapy for patients with cancer and exemplifies the integration of general knowledge in individual patient data. The second one deals with order entry for radiology and discusses data exchange within a hospital. Both examples provide with very detailed medical knowledge. The problem oriented approach will lead to a huge number of such presentations. The closer such a presentation fits an actual problem the better the health care delivery will be supported.

Glasgow Coma Scale

The Glasgow Coma Scale is a highly specialized example to show how the system can support the physician with general information about a medical technique. The score is used in intensive care to give a general status of the patient.

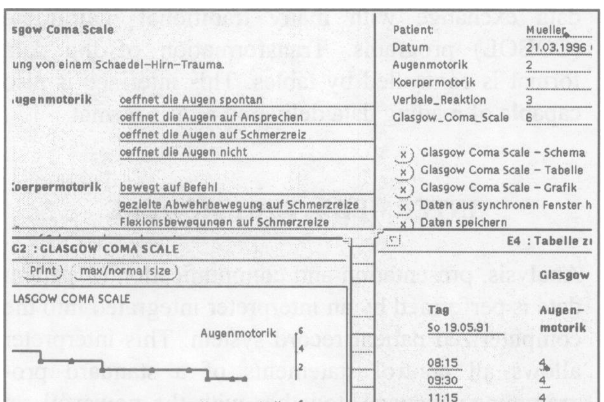

Fig. 4: Glasgow Coma Scale

Fig. 4 shows part of four different windows. The small upper right window allows the entry of new score values. Medical experts will enter score values directly through this form for sake of speed. Support on calculating score values can also be requested through this form. The window on the left hand side shows the definition of the score values. The explanation lines are clickable. Score values are generated this way and shown beneath the explanation. Integration of patient independent information like guide lines can be achieved by this means. Below the entry window the history of the patient is shown both in graphical and tabular form.

Order Entry

Order entry for diagnostic radiology is a good example for communication in a hospital setting. Orders have to be checked because e.g. other examinations may have to be performed before the x-ray image can be requested. The order is completed on the ward and sent to the department of radiology. Time and date of the appointment is returned to the ward via the inter-hospital communication link. X-ray images are taken, transmitted to the picture archiving and communication system (PACS) where reports are written by the radiologists. Finally, images and the report are sent to the ward where they are recorded in the CPR.

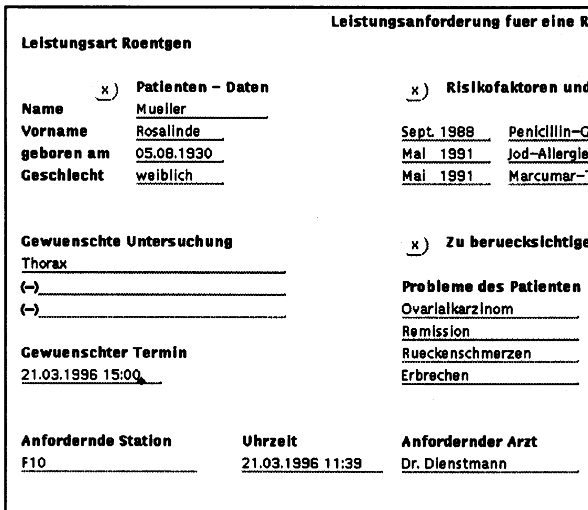

Fig. 5: Order Entry

Fig. 5 shows such a form for order entry. Basic information from the CPR is automatically entered in the form. Diagnosis and risk factors are also copied from the Computerized Medical Record. The physician has to enter the requested examination.

DISCUSSION

Existing systems are essentially based on centralized systems that date back to the early sixties. Mainframes running complex programs served a large number of (alpha) terminals. Centralized computing centers offered the required computing power. Client-Server architectures did not essentially change the organizational structure.

A first important approach is the HELP-system[6]. Its conception is influenced by the idea to support medical decision making with general medical knowledge. The Regenstrief Medical Record System[7] offers a central data dictionary and time oriented recording of data.

The development of a problem oriented medical information system (PROMIS) by Weed[8] is of special importance. His conception is patient centered, for every patient a medical file is required that shows problems and the respective therapeutical methods. Progress in treatment has to be clearly shown. Such demands are not new nowadays[9], on the contrary they define medical and rational procedures and methods.

The advent of Smart cards and global network technologies (e.g. Internet) made CPRs feasible that can be transferred to other physicians or hospitals. This approach greatly benefits from ideas of existing systems. It is based on the idea of independent partners exchanging information about patients. Therefore it can (technically) easily be extended from a hospital setting to a nationwide information system.

CONCLUSION

Traditional computerized patient systems are basically intended to support health care delivery in a single hospital setting. The problem oriented approach and the integration of general medical knowledge offers support for health care professionals.

Global communication techniques give the chance to cross the border of hospitals and to create telemedical patient records. Problem oriented patient records that accompany the patient throughout his or hers whole life now seem possible. They require standards that are accepted by all institutions over a large time span. A large effort still has to be made to define such structures and convince the public to implement them.

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